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Note on an enquiry by the Government of India
into the relation between forests and
atmospheric and soil moisture, in India

BY

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Note on an enquiry by the Government of India into the relation between forests and atmospheric and soil moisture, in India.

SINCE 1906 an exhaustive enquiry on this important subject has been made throughout British India. In that year the Right Hon'ble John Morley, P.C., O.M., His Majesty's Secretary of State for India, forwarded for the consideration of His Excellency the Right Honourable the Governor-General of India in Council, a communication from Dr. J. Nisbet, formerly a Conservator of Forests of the Indian Forest Service, in which it was remarked that the relation of forests towards the mitigation of the severity of famines in India seemed never to have been adequately considered.

Dr. Nisbet pointed out that although as far back as the year 1847 the Court of Directors had ordered an enquiry touching partly on this subject, no full investigation and report appeared to have been made either in connection with this enquiry or at any subsequent time. He was of opinion that there were doubtless large, and more or less barren, tracts in all of the provinces, having only a scanty and precarious rainfall, where much might be done to improve the character of such vegetation as springs up spontaneously, and to make this latter of greater economic utility, both directly and indirectly.

The relation between forests on the one hand, and atmospheric and soil moisture on the other, had not, he considered, received the attention of which it was worthy from any of the Indian Famine Commissions that had reported during the preceding 30 years, and he suggested for consideration, whether it might not be advantageous to institute an enquiry of this nature for the benefit of the natives and the agriculture of India.

2. Dr. (now Sir) William Schlich, formerly Inspector-General of Forests to the Government of India, in a memorandum which accompanied the Secretary of State's despatch, pointed out that the subject dealt with in Dr. Nisbet's letter was a very difficult one and that even after many years of careful and minute investigation in Europe, no final conclusions had been arrived at, as to the influence of forests on rainfall. He considered that, in India, such influence, even if it existed, would be very small compared with other agencies that govern the rainfall of the country, such as the heating of the land in spring.

and the consequent in-draft of moist sea-air, the rate at which the south-west trade winds press northward, and the influence of the snowfall in the Himalayas. As regards the preservation of moisture, he pointed out the decided importance of forests, specially in districts subject to drought, more particularly as regards the catchment areas upon which irrigation water is dependent. Dr. Schlich was inclined to doubt whether a general investigation of the subject would be advantageous, since the necessary data were not available to arrive at any practical conclusion.

3. At about this time, however, Mr. (now Sir) Eardley-Wilmot, late Inspector-General of Forests to the Government of India, issued some valuable notes on the influence of forests on the storage and regulation of the water-supply ; and the Government of India in view of the great importance of the subject to the agricultural population decided to call for a full and systematic enquiry. Accordingly they invited the attention of all Local Governments and Administrations to the remarks made by Dr. Schlich and Dr. Nisbet and to the notes written by Mr. Eardley-Wilmot, and desired them to institute enquiries and collect what information was available.

4. In addressing the Provincial Governments the Government of India pointed out that the prosperity of the agricultural population depended to a great extent on the distribution of available moisture, not only in the form of rainfall but also of the surface flow of streams and rivers, and of the underground flow from which is drawn the supply of water in wells.

The influence of forests on the water-supply of the country could, it was thought, be considered from two points of view. First there appeared to be grounds to believe that the actual amount and distribution of the rainfall, although chiefly dependent upon great air movements such as that of the monsoon, was affected by the extent to which the country over which the moisture-bearing currents passed was covered with vegetation or consisted of bare hills or barren plains : but from the nature of the case it would require a long series of careful observations to determine the effect of the destruction of forests on the actual amount and distribution of the rainfall. But the second branch of the subject was one regarding which it was not so difficult to collect and weigh evidence, namely, the effect of denuding a country of its forest vegetation on the surface flow of the surplus rainfall, and on the underground flow of that part of the rainfall which sinks into the soil, and either reappears on the surface further down in the form of springs, or feeds the great underground currents which pass down

the valleys towards the sea ; it was pointed out that there was ample evidence in all parts of the world, and in India itself, of the great damage caused by careless clearing of forest areas, especially near the sources of rivers and streams. One marked effect of such action was that the rainfall, instead of sinking slowly into the ground and running off gradually during a lengthened period, rushed down in destructive torrents which excavated for themselves deep ravines and carried down large quantities of débris to the ruin of the cultivated fields below, and after they had covered large areas of level country with injurious floods, passed off uselessly into the sea.

On the other hand, when the catchment area of a river (including not only the country near its sources, but the whole area from which was drawn its supply of water), was fairly well-wooded, the rainfall was to a large extent retained by the vegetation, and in the soil on which it grew, the floods were less violent and destructive, and were spread over a much longer period. Moreover, a larger proportion of the rainfall sank into the ground and kept up the level of the underground water-table ; and the whole area within reach of the influence of the rivers and its tributaries, and of the underground water-table was benefitted by a more equitable distribution of moisture and temperature throughout the year.

The question, therefore, not only affected the interests of the inhabitants of the country near the sources of the rivers, but was of immense importance to the future welfare of the distant agricultural population whose crops depended upon security from destructive floods and on a favourable distribution of the total available supply of water, and there appeared to be some reason to believe that during the last century, in many parts of India, there had been a marked deterioration in this respect. Floods were believed to be more destructive than formerly ; land which used to produce crops had become covered with sand, good soil had been carried away by the erosion of torrents, streams and rivers shrank more rapidly in the dry season, and the level of the water in wells had in places sunk to a considerable extent. It was estimated by the Irrigation Commission that 35 per cent. of the total rainfall of India was carried away by the rivers, and that 87 per cent. of the total surface flow passed to waste in the sea. The Commission dwelt on the importance of the sub-soil water to well irrigation, but they had not, however, considered the question of how to arrest a larger proportion of the surface flow and make it available for the distribution of moisture over the land, by retaining it in the catchment area with the aid of vegetation, and thus rendering its flow more equable, and utilizing it to increase the underground water-supply.

The question derived additional importance from the extent to which agriculture in India was dependent upon weirs and canals which intercepted a considerable proportion of the surface flow of the rivers and distributed it over the land.

For the full use of the water-supply in this manner, for the irrigation of crops, it was necessary that the flow of the rivers should be equable; and when, owing to the destruction of forest vegetation in the catchment areas, the rivers came down in heavy floods at certain seasons, and dried up at others, the utility of the canals was greatly diminished, and the quantity of crops which could be grown by irrigation was lessened. There was also the danger that a heavy flood might carry away part of the head works and bring ruin on the large population dependent on the maintenance of irrigation from the canal.

Other interests were also liable to be affected. For instance, in many parts of India, violent floods were apt to carry away bridges and embankments, interrupt communication by railway and road, expensive repairs being rendered necessary.

It was recognized that the question afforded a wide scope for enquiry, and that there would probably be some difficulty in dealing with it in all its aspects, but it was suggested the enquiry, which the Government of India desired should be made, might suitably embrace the following matters :—

Was there any reason to believe that during the last half century the amount and distribution of the rainfall over large tracts of country had altered permanently for the better or for the worse?

Had there been any permanent change in the level of the underground water-table?

Had the flow of rivers and streams become less equable than before, or in other words, were floods shorter in duration and more violent and destructive, and did the streams dry up more quickly in the dry season, and had this resulted in serious injury to the interests of cultivation or to other interests?

Where such a change had taken place, was there any reason to connect it with the destruction of forest vegetation in the catchment areas of the rivers and streams?

What evidence was there that the catchment areas had been denuded to any extent during the last half century?

What steps had been taken in the province to check the destruction of forest vegetation, and what had been the effect of such measures in preventing the denudation of

catchment areas and in maintaining an equable distribution of the available moisture?

Was there sufficient ground for taking further measures to check the destruction of forests, or to re-forest areas which had been denuded of their forest growth. And, if so, what measures were recommended?

In connection with the last question it was pointed out that it was desirable to bear in mind that restricted measures would often affect the immediate interests of the population living in the neighbourhood of the areas which it might be desired to keep under forest growth. In some cases they would ultimately be beneficial to that population itself, or to its posterity; but in others they would be justifiable only by regard for the interest of a distant population dependent on an equable distribution of the water-supply, and in such cases it would be necessary to consider whether the interests of the distant agricultural population were sufficiently important to justify the imposition on the liberty of the people residing near the forests of restrictions which they would necessarily feel to be vexatious.

3. As a result of this comprehensive enquiry instituted throughout India, a great quantity of information was collected and forwarded with the opinions of the Local Governments concerned for the consideration of the Government of India.

It is not within the scope of this paper to do more than to summarize briefly the information supplied and the views expressed, but before doing so it will be convenient to show the distribution, by provinces, of the areas of all forest lands under the control of the Forest Department throughout British India. The areas at the end of June 1913 were as follows:—

Area of all forest lands under the control of the Forest Department on the 30th June 1913.

PROVINCE.	TOTAL AREA IN SQUARE MILES.					Percentage of forests to whole area of province	REMARKS.
	Name.	Area in square miles.	Reserved.	Protected	Undeveloped State.	Total.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bengal	78,875	(a) 2,671	(b) 1,711	4,000	10,613	13.5	(a) Excludes 17 square miles of reserved forest not under the management of the Forest Department. (b) Excludes 34 square miles not under the control of the Forest Department.
United Provinces	106,773	(c) 4,117	(d) 30	20	4,170	3.0	(c) Includes 156 square miles of leased forests.
Punjab	90,030	(e) 2,205	(f) 2,200	1,311	8,710	0	

Area of all forest lands under the control of the Forest Department on the 30th June 1913—contd.

PROVINCE.		FOREST AREA IN SQUARE MILES.				Percentage of forests to whole area of province.	REMARKS.
Name.	Area in square miles	Reserved	Protected.	Unclassed state.	Total.		
(1)	(2)	(3)	(4)	(5)	(6)		
Burma (including Shan States)	224,595	27,023	..	106,592	133,615	59.5	
Bihar and Orissa	82,080	1,723	(g) 1,056	..	2,770	8.3	(d) Excludes 0,006 square miles of district protected forests which it is proposed to bring under the control of the Forest Department.
Assam	48,015	4,381	..	18,200	22,671	46.3	(e) Includes 307 square miles of leased forests but excludes 100 square miles of reserved forests not under the control of the Forest Department.
Central Provinces (including Berar).	69,876	20,572	..	..	20,572	20.0	(f) Excludes 20 square miles not under the control of the Forest Department.
Coorg	1,682	520	..	..	520	32.0	(g) Excludes 925 square miles of other protected forests not under the management of the Forest Department.
North-West Frontier Province.	13,184	(h) 230	(i)	..	230	1.8	(h) Excludes 14 square miles of Military and Civil reserved forests.
Ajmer	2,767	142	(n)	..	142	5.1	(i) 121 square miles of Civil protected forests are not shown.
Baluchistan (Portions under British Administration).	(o) 54,228	313	..	472	785	1.4	(l) Reserved lands.
Andamans and Nicobars.	3,143	166	..	2,015	2,171	99.1	(l) Includes 331 square miles of leased forests and excludes 2,054 square miles of forests in charge of the Revenue Department.
Madras	142,204	18,041	..	(L) 825	10,406	18.7	(m) Includes 325 square miles of leased forests and excludes 548 square miles of protected forests in charge of the Revenue Department.
Bombay (including Sind).	123,301	(l) 11,067	(m) 405	..	12,462	10.1	(n) There are only 115 acres of protected forests in Ajmer.
Total 1912-13	*1,070,163	96,807	8,492	133,564	233,023	22.1	(o) Revised Survey figures.
" 1911-12	*1,071,051	96,148	8,406	133,316	242,000	22.7	
" 1910-11	*1,071,010	96,387	8,607	133,584	242,478	22.7	
" 1909-10	*1,042,718	96,174	8,614	140,263	245,555	23.5	
" 1908-09	*1,010,872	94,501	8,636	138,978	241,774	23.2	
" 1903-04	*1,022,652	91,562	8,805	181,260	282,701	22.6	
" 1898-99	*1,001,051	89,148	8,483	99,565	128,190	12.2	
" 1893-94	*1,005,520	71,589	7,679	24,680	103,848	10.9	
" 1892-89	*800,472	54,321	25,350	18,618	101,191	11.6	
" 1883-84	*921,470	48,705	6,655	10,862	74,212	8.1	

* Includes area of Shan States i.e., 54,728 sq. miles.

The actual distribution of the forests is shown on the attached map and a chart showing the average annual rainfall of India for the year 1913 is also appended.

6. It will be observed from the statement above that whilst the total percentage of forest areas to the combined areas of all the provinces is 22·1 or nearly one-fourth, their distribution is, however, very unequal, thus of the more important provinces it will be seen that Bombay has approximately 10 per cent. of forests, Madras 13 per cent., Central Provinces 20 per cent., Bengal 13 per cent., Burma 59 per cent., Assam 46 per cent., whilst the Punjab has only 9 per cent., the United Provinces 4 per cent., and Bihar and Orissa 3 per cent.

It should, however, be noted that the statement above does not show the areas of private and other forests not under the control of the Forest Department, nor the area of forests in the Feudatory and Tributary

* Excepting the area of the States^{*} under the direct political control forests in the Shan States. of the Government of India. The total area of such forests must be considerable.

The statement below shows approximately the areas of these States, and the areas of private and other waste lands.

Statement showing areas (on 30th June 1913) of Feudatory and Tributary States under the control of Local Governments and Administrations, and private and other waste lands, the forest area of which is not known.

Province.	Total area of Province.	Deduct Feudatory and Tributary States.	Balance under the Government of India.	Area cultivated.	Forests under control of the Forest Department.			Balanced including private and other forests, waste lands and areas for which no returns are available.	Proportion of forests to area under the Government of India.
					Reserved.	Protected.	Unclassed.		
1	2	3	4	5	6	7	8	9	10
Bengal	81,268	5,301	78,975	38,935	1,871	1,711	4,630	10,012	0.18
United Provinces	112,362	0,789	106,773	65,010	4,117	30	29	29,308	3.86
Punjab	13,949	39,929	06,050	34,777	2,295	6,200	1,311	4,170	40,987
Burma	176,113	0,216	165,897	20,814	27,023	..	106,492	111,015	2.23
Bihar and Orissa	111,629	28,018	83,080	13,037	1,723	1,050	..	2,770	37,111
Assam	61,768	12,453	48,016	8,025	4,381	..	18,290	22,071	2,08
Central Provinces	131,061	31,168	99,876	39,104	29,572	..	..	29,572	17,310
Coorg	1,528	..	1,582	291	620	..	..	520	8.96
North-West Frontier Province.	13,464	220	13,181	3,570	230	..	..	236	20.10
Ajmer	2,707	..	2,707	*355	113	..	..	142	2,370
Madras	162,501	0,007	142,294	51,660	18,041	..	825	10,406	13.10
Bombay	187,117	0,161	123,301	40,380	11,067	405	..	12,102	0.71
Total	1,170,113	203,040	1907,001	357,473	66,308	8,492	131,077	† 255,907	303,024
								0.97	

* Including Pagan Manipur in Central India.

† Excluding Daulatistan and Andamanas.

7. As regards the first question, *as to whether during the last half century the amount and distribution of the rainfall over large tracts of country had altered permanently* :—The Madras Government, after an examination of the available statements of rainfall for the Presidency, expressed the opinion that there was nothing in these to support the view that there had been any marked change in the rainfall during the past 50 years. It was shown that for the Madras City, for which records were available for nearly a hundred years, there was nothing to show that the rainfall had diminished. The statistics for decades showed that the decades with the highest average rainfall were 1841-1850 (54·13 inches), and 1881-1890 (53·34 inches), while the lowest rainfall occurred in the decade 1831-1840 (43·84 inches). The figures for neighbouring districts Chingleput and North Arcot, which both had the highest average rainfall in the decade 1881-1890 confirmed this result.

An examination of the averages for the remaining districts of Madras were found to prove conclusively that there had been no falling off in rainfall over large areas, indeed in some districts, e.g., Godavari on the east coast and South Canara on the west coast, the decade average had shown an almost progressive increase, but in most cases no decided movement was visible.

In Bombay, a similar conclusion was arrived at. It was remarked that there was a severe drought in 1876 and in 1899 and less severe shortness of rainfall in 1892 and in a few years subsequent to 1899, but there was no indication of a permanent decrease or increase in the general precipitation.

The opinion formed in Bengal, after an examination of such records as were available, was that, although there appeared to be no reason to suppose that the amount of rainfall had decreased throughout the province, the results were considered inconclusive.

In the United Provinces, where rainfall figures for 58 years were available, it was found that periods of unusually heavy rainfall alternated with those of short rainfall, but no permanent change was observable. The mean rainfall for the first 25 years for which figures were available, amounted to 36·43 inches, and for the last 29 years to 37·97 inches. There appeared to be nothing to show that there had been any permanent alteration in the amount and distribution of the rainfall during the preceding 50 years.

The report of the Director-General of Observatories dealing with the amount and distribution of the rainfall in the Punjab for the period 1863-1907 went to shew there was little to suggest a gradual climatic change. The amount of rain increased to a maximum in 1893, 1894, then fell

suddenly and had been increasing again since 1899. Although there was no proof of any permanent climatic change there had been a tendency in the Punjab, and other parts of North-West India, for rainfall to increase to a maximum between 1892 and 1894, to sink to a minimum in 1899 ; and to improve slowly since that date. It was not thought that these changes were connected with any increase of irrigation or with the destruction or re-establishment of forests.

From an examination of the statistics of the rainfall for the period during which they had been collected, the conclusion arrived at by the Government of Burma was that they afforded no ground for the belief that there had been any significant variation in the amount of rainfall. It was pointed out that the numerous tanks and irrigation works of ancient date were presumptive evidence that deficiency of rainfall was not a purely modern phenomenon. A comparison of the conditions now prevailing in the dry zone of Burma with those, which, from Mr. Yule's " Narrative of the Mission to the Court of Ava in 1855," prevailed at that date, did not support the theory that conditions of rainfall have materially changed. It was generally admitted by Forest officers that there were no observed facts in Burma to justify the assertion that there had been recently any decrease in rainfall. The evidence to the contrary was of trifling weight. The phenomenon chiefly urged, viz., the decrease in the cultivation of unirrigated rice was probably to be explained by other causes.

The result of the enquiry in Eastern Bengal and Assam was that the quantity of rainfall could not be shown to have decreased generally during the years for which more or less accurate statistics were available, though there appeared to have been a progressive decrease in the districts of Goalpara, the Khasi Hills, Darrang and Nowgong. It must, however, be borne in mind that the circumstances of Eastern Bengal and Assam as a whole and of Assam in particular, are exceptional. Lying as it does in the direct line of the Bay of Bengal current, intersected with hill ranges covered for the most part with vegetation, and shut in on the north by the immense snow ranges of Tibet and Bhutan, which here approach the sea more closely than in any other part of India and no doubt cause a precipitation of rain, the climatic conditions of Assam differed from those of any part of India and no deductions made in regard to Assam could possibly be applicable to India as a whole. It may be mentioned that it is in the Khasi Hills of Assam that Cherrapunji, which has the greatest rainfall in the world, is situated.

Sir Charles Bayley, then Lieutenant-Governor of Eastern Bengal and Assam, remarked that the question of rainfall was one which he had constantly discussed with native gentlemen, and especially with

elderly men, and he had no hesitation in saying that, at any rate in Central India, and Hyderabad, where deforestation and jungle cutting have until quite recently proceeded for many years with little restraint, there was a general impression that the rainfall had largely decreased within the memory of living men.

In the Central Provinces, apart from oral evidence, which could not be accepted as reliable, there was nothing to show that the amount or distribution of the rainfall had altered for the worse. On the contrary, the rainfall statistics showed on the whole an increase.

The rainfall figures in Coorg for the preceding 45 years were as follows :—

1863—1872	.	.	.	.	.	.	.	123·17 inches.
1873—1882	.	.	.	.	.	.	.	129·71 "
1883—1892	.	.	.	.	.	.	.	120·23 "
1893—1902	.	.	.	.	.	.	.	119·27 "
1903—1907	.	.	.	.	.	.	.	125·00 "

These figures could not be held to indicate any permanent alteration in rainfall, a conclusion generally supported by the experience of Coffee planters in Coorg.

An examination of the available material in Baluchistan afforded no evidence of any marked alteration in the amount or in the local distribution of the rainfall during the period for which records existed. There was some evidence that the seasonal distribution of the rainfall in the mountainous area had in recent years altered for the worse as regards irrigation, the snow-fall in the winter had been less and the warm spring rains heavier, but it seemed probable that this was merely a temporary fluctuation. The conclusion arrived at was that on the whole there were good reasons for believing that within the preceding half century there had been no marked permanent alteration, either for the better or for the worse, in the amount of the rainfall, this conclusion derived added importance from the fact that local denudations of forest growth had undoubtedly taken place during our 30 years' occupation of Baluchistan.

In the North-West Frontier Province there was no reason to believe that there had been any permanent alteration in the rainfall. In stations, as far apart as Dera Ismail Khan and Pesluwar—the only stations in the Province with over 40 years of rainfall records—the average rainfall calculated over two periods of 22 years each (from 1863 to 1881 and 1885 to 1906) had altered little. The average for the first period was 10·94 inches and for the second period 11·01 inches.

The results of the enquiries throughout the Provinces of India, as summarized above, must be held to show that there has been no permanent change in the amount of rainfall over large tracts, either for the better or worse.

Such evidence as is available in India points to the conclusion that the influence of forests probably tends to increase the rainfall but not in any marked degree. The main rainfall in India depends on the monsoon currents which are effected by conditions obtaining outside India, and not by any destruction or re-establishment of forests.

A note on the effects of forests on rainfall by the Director-General of Observatories will be found in Appendix II. It will be observed that Dr. Walker is of the opinion that the effect of forests on the rainfall in India is small and probably does not reach 5 per cent.

8. As regards the question *whether there had been any permanent change in the level of the underground water-table*, it must be admitted that although a considerable amount of information was collected there were no satisfactory data to support any definite conclusion.

There was a certain amount of evidence that the level of the water-table had fallen in Chota Nagpur and Orissa. It had certainly fallen in the Kheri, Bahrach and Pilibhit Districts of the United Provinces, though there was nothing to show that this lowering of the water-level was of a permanent nature, for it appeared to be ascribable to a succession of years of decreased rainfall, which culminated in 1908. Some definite instances of a lowering of the water-level in parts of Burma were brought forward, but the evidence was considered by the Local Government to be wholly inconclusive, and it was not considered that in this Province there was sufficient evidence to show that there had been any important change in the level of the underground water-table. In Eastern Bengal and Assam there was testimony to show that the sub-soil water-level had fallen and the same may be said of the Central Provinces, but there was an absence of accurate observation extending over a lengthened period, and nothing to show that the subsidence was a permanent one. It was reported that the average level of the sub-soil water in Jaipur State had fallen 10 to 15 feet in the last few years preceding 1907, but this was attributed to a series of years of somewhat diminished rainfall. The underground water-table in Ajmer, and probably also in Merwara, varied enormously in direct proportion to the rainfall. In the Quetta District, Baluchistan, the water-level had sunk

Note.—A report by Dr. G. T. Walker, M.A., F.R.S., Director-General of Observatories in India, on the evidence from meteorological records of any apparently permanent change in the amount and distribution of the rainfall over the different large areas of India and on the probable causes of such changes, will be found in Appendix I.

but this was believed to be partly due to years of deficient rainfall and partly to the system of irrigation known as *karez* which tended to lower permanently the water-level (*karezes* are simply artificial drains or streams tapping, by means of their ingeniously contrived tunnels, the water-bearing strata which form the underground reservoirs of the country. Their flow is perennial, and, as a rule, cannot be stopped at seasons when the water is not needed for irrigation ; consequently, where *karezes* are numerous, a vast amount of sub-soil water, which in a country not thus artificially drained would be retained in, or percolate very slowly through, the water-bearing strata, annually runs to waste).

In the North-West Frontier Province, the records showed that in the tract irrigated by the Lower Swat River Canal there had been a steady rise of 13 feet in the water-level, during the preceding nine years ; while in the Punjab variations in the sub-soil level, were attributed to the action of the Irrigation Department. New canals were opened out from time to time and the rivers drained in consequence.

There were indications in Bombay that the shortness of the rainfall in some years subsequent to 1899 had led to a lowering of the level of the sub-soil water, but there was no reason to believe that the former level would not be restored by a series of years of normal rainfall.

As regards Madras, it was stated that there was no reason to suppose that any permanent change had taken place in the level of the sub-soil water. The statistics of rainfall showed that there had been no marked change in the amount of rain recorded, and there was, therefore no *prima facie* reason to suppose that there had been any change in the amount of subterranean supplies of water ; in the absence of any trustworthy records of sub-soil water-level no reliable information could be given.

The only conclusion to be arrived at from the information supplied by Local Governments was that, in the absence of reliable data lasting over a prolonged period, it could not be said whether there had been any permanent change in the level of the underground water-table, generally speaking; it appeared that the level depended on the rainfall and varied directly with it.

9. Regarding the question whether the flow of rivers and streams had become less equable than before, or were floods shorter in duration and more violent and destructive, and did streams dry up more quickly in the dry season, and had this resulted in serious injury to the interests of cultivation or other interests :—The Madras Government forwarded statements showing (i) the maximum flood levels and the dates on which

* *Kisna, Tungabhadra, Pen-*
ner, Paler, Ponnar, Cauvery. rivers of the Presidency * in regard to
which information was available ; (ii) the maximum flood-levels in the same six rivers reduced to 5-year

averages : and (iii) the discharge of the same rivers, during each month of the year for 25 years.

It was observed that in three cases the year of maximum of flood level was 1903, in one case 1896, and in two cases 1889. Little importance could, however, be attached to the occurrence of a single high flood without complete information as to the rainfall in the catchment area affected. Thus the flood of October 1903, in the case of the Kistna, was due to abnormally heavy rain over a large area of the Nizam's dominions. Such complete information was not available and any conclusion to be drawn from the occurrence of these floods was to be deprecated. From the statement showing the maximum flood levels it was noticed that, in the case of the Kistna and Tungabhadra, the higher average flood levels (allowing for changes in crest-level) were recorded in the 5 years 1880-1885 ; in the case of the Penner in the years 1886-1890; in the Paler in the years 1880-1882 ; and in the case of the Cauvery in the 5 years ending 1901. In the case of these figures also it was apparent that no certain conclusions could be arrived at without a complete study of the statistics of rainfall in all parts of the catchment area.

From an examination of the statement showing the discharges of the same rivers, there seemed to be no evidence of any increase in floods during the monsoon months of the year. In the case of the Paler and the Pouniar, there appeared to be a distinct reduction in the discharges during the months of maximum rainfall, a result attributed to the larger extent to which the supplies in these rivers are intercepted by irrigation works, notably in the Mysore State.

From the figures showing discharges in the hot weather months, March, April and May, it was difficult to find any evidence of any deterioration which could be connected with the clearance of forests. The record of the Kistna river at Bezwada certainly showed a diminished hot weather flow during the last 10 years as compared with the preceding 15 years ; but this coincided with a corresponding reduction during the monsoon months also, thus pointing either to a diminished rainfall in the catchment area of the river, or to increased interception of supplies for irrigation purposes. No definite conclusion could be arrived at from the information available.

It was observed by the Government of Bombay that the violence and duration of floods depended on the intensity of storms, or on the steadiness and continuity of the rainfall, or its irregularity. The drying up of streams in the hot weather proceeded more rapidly in years of short or capricious rainfall, less so in years of steady or full rainfall. The results of the enquiries made went to demonstrate that there was nothing to show, nor any reasons for believing that in the

respects enumerated above conditions differed from those which obtained in years antecedent to 1858.

As regards the question in Bengal, it was pointed out that, without a careful comparison of the rainfall throughout the entire catchment area of any river, and of the flood levels at any particular point some 20 years ago with those of the present day, it would be impossible to arrive at any exact conclusion. Besides excessive rain, there were other causes of floods, such as the silting up of river beds, while perhaps the result of excessive erosion due to denudation of the catchment area, again produced variations tending to detract from, or even to nullify conclusions drawn from comparisons of the height of floods. The belief was widely prevalent, especially in Orissa, that floods in the Brahmini, Mahanadi, and other rivers, were more frequent than formerly, and it was certainly the case that the catchments of these streams had suffered, over wide areas, from the overcutting of timber. But such general beliefs and observations could only be considered as unreliable, and the only satisfactory evidence that could be obtained was by the comparison of streams which flowed through reserved forests with those whose catchment area had been stripped of their protecting verdure. The Koina and Rora rivers in Singbhum offered a contrast of this sort. Both of these streams were 35 to 40 miles in length. The former drained a tract of country of which 80 per cent was reserved forest, and held a plentiful supply of water; while the catchment area of the latter was almost denuded, and its waters ran very low, even in the cold season, and dwindled away to nothing during the hot weather. The question whether or not denudation in the Feudatory States exercised a direct influence upon floods in Orissa had been considered by a Committee, and it was concluded that such denudation could not be without effect on the flow of the rivers in the flood basin. In a note on the connection between rainfall and flood level in the Brahmini river, it was shown that the rain which fell about its upper course ran off the watershed with extraordinary rapidity. It was certain that in recent years destructive floods had been frequently caused by the rivers which discharged through the low lands of Orissa, and it was at least probable that denudation of the catchment areas had been a contributory cause of these floods.

The reports of the Irrigation Department in the United Provinces showed that there was a general belief that the floods in the Siwaliks were of shorter duration and more violent in recent years than in the past. The hills from which these streams took their rise were covered with light deciduous forest, which had been under strict conservation for over 30 years. It was hardly conceivable that the protection of these forests, more especially from fire, could have increased the run-off.

More probably the conservation of these forests had decreased the total amount of the run-off, but, on the other hand, had caused the streams to become confined to more definite channels owing to the forest growth having encroached on the river beds, and thus the run-off, though decreased in quantity, might be discharged more quickly.

Moreover, the rapidity of the run-off depended to a great extent on the degree of heaviness of the rain, though in the absence of statistics to show the duration and fall of individual showers, it was difficult to compare the floods of different years. It might happen, for instance, in the same forest in two years of the same total annual rainfall that the run-off varied enormously. If the rainfall was light or moderate, and the showers protracted the run-off would be comparatively small, whereas if the showers were heavy and of short duration the run-off would be excessive.

A recent shrinkage in the streams fed from springs in the Tarai, which supplied the Rohilkhand Canals, had been observed, but it was not possible to say whether this was due to less absorption in the catchment area, or to a larger use of the river water in the Bhabar Canals, or to increased cultivation in the Tarai, or to a combination of these three factors. In any case it did not appear that so far any serious injury to cultivation or other interests had resulted.

The records available in the Punjab did not extend sufficiently far back to admit of any definite conclusions being drawn from them, specially in the absence of information as regards rainfall over the catchment areas. In the case of the Indus at Attock, where records for 40 years existed, there seemed no evidence that any marked changes had taken place either in the number, intensity or duration of floods.

As a case of streams which had done harm by flowing violently for short periods, and eroded good cultivated land was mentioned the torrents that ran off the northern slope of the Pabbi range of hills into the River Jhelum. It was alleged by the cultivators that these streams did much more damage by erosion than they did formerly when the Pabbi slopes were covered with trees and vegetation.

In the case of the Siwalik Hills, it was believed that the floods in the hill streams were shorter, and more violent and destructive than they used to be, and that the streams dried up more quickly in the dry season. The history of the Hoshiarpur Chos clearly demonstrated the damage done by torrents to the land below the hills. In the Pabbi Hills of the Gujarat district and perhaps in some of the lower Himalayas and in the Salt Range, a similar state of affairs was suspected

to exist, but elsewhere there was no evidence of a change in the character of the streams.

In Burma, although there was some evidence to show that harm had been done by torrents in the way of erosion, the destruction of culturable land and the formation of ravines, and sand banks in rivers, the damage was not all, or even mainly, of recent date ; but there was little or no reliable evidence to show that floods had become more violent, or that extensive damage had been caused by them. Some instances of the washing away of surface soil from the denuded hills in the Southern Shan States were given and of the formation of ravines by the complementary action of sun and rain, and some cases of the failure of streams, but on the whole it was doubted whether a stronger assertion could be made than that certain streams appeared to run dry earlier than was formerly the case. There was little evidence of serious injury to cultivation.

While there was no direct evidence in Eastern Bengal and Assam, the general trend of opinion was that, in the majority of districts, floods were shorter in duration and more violent and destructive in character than formerly, and that streams dried up more quickly in the dry season, and that cultivation and other interests had suffered in consequence, but it seemed doubtful whether those who had advanced these opinions had given sufficient consideration to the marked changes in river levels which followed the earthquake of 1897.

In the Central Provinces, the opinion was held that floods were less frequent and less violent and destructive than formerly. There was some evidence to show that streams dried up more quickly in the dry season, but it could not be considered in any degree as conclusive.

As regards Baluchistan, and the North-West Frontier Province, there was no evidence to show that there had been any marked change in the duration or violence of floods, or in the drying up of streams. The records of the flow of the Swat River at Abazai, and the Indus at Attock, which extended back for 30 and 40 years, respectively, did not support the theory of any appreciable change.

On the whole, therefore, save perhaps in some of the cases mentioned above, it was considered that, generally speaking, it could not be said that the flow of rivers and streams were less equable, that floods were shorter in duration and more violent, and that streams dried up more quickly.

10. It had been asked whether in cases where such changes had taken place, was there reason to connect them with the destruction of forest vegetation in the catchment areas of rivers and streams, but it will be seen from the above that on the whole there was little authentic information to point to any very marked changes. In Eastern Bengal and Assam, where there

was some reason to believe that extensive clearances in catchment areas had in a measure affected the flow of rivers and streams, it was pointed out that the rapid growth of vegetation on areas abandoned after cultivation had tended to neutralise any evil effects in that Province, and though damage had been done in some cases to cultivation the injury caused had not been very extensive. In the United Provinces the only definite case in which floods were believed to be more violent and of shorter duration, namely in the Siwalik torrents, this was certainly not due to the destruction of forest vegetation. In fact the Siwalik Hills afforded a good example of forests which had not been destroyed or encroached upon of recent years. They are, as they were, thirty years ago. The slight diminution observed in streams rising in the Tarai might be partially due to denudation of forests in the Tarai, but more probably only to several consecutive years of deficient rainfall. This was certainly the reason for the deficiency recently observed in the streams rising in Kheri. The Irrigation Department, moreover, pointed out that there was no appreciable falling-off in the water-supply of the Jumna or the Ganges. On the whole, then, it was concluded that there was no evidence to connect shortage in the water-supply with denudation of forest vegetation.

The conclusion arrived at in Bengal, where in recent years destructive floods had been frequently caused by the rivers, which discharged through the lowlands of Orissa, was that it was at least probable that denudation of the catchment area had been a contributory cause of these floods, and it was believed in Assam that extensive clearances in the catchment areas had in some cases led to a less equable flow of the rivers and streams.

It was pointed out that, as regards the Central Provinces, it could not be said that any wholesale denudation of forests had taken place. The sources of such of the larger streams as took their rise in the Province could mostly be traced to the Satpura Watershed, the forests of which had improved rather than deteriorated during the preceding 25 years. In Burma, it was not considered that any relation of cause and effect had been established on the evidence furnished by the enquiry, between such denudations as had occurred within living memory, and the somewhat conjectural increase of violence combined with a shorter period of the floods of streams.

In the Punjab, it was admitted that the damage which had been caused in the Pabbi Range, in the Hoshiarpur Chos in particular, and in the Siwaliks generally, in the Lower Himalayas, and the Salt Range was due to denudation of the forest growth.

In Madras and Bombay, no definite conclusion was arrived at, but it was not apparent that any change had taken place.

Generally then, the conclusion to be formed as regards this question followed that of the preceding one, that in most Provinces no serious damage to the flow of rivers had taken place and no great injury had been done to cultivation. There were, however, several local exceptions and much damage had been done in the Punjab, in Bengal, and to a less extent in Eastern Bengal and Assam. Where damage was acknowledged, it was on the whole admitted that this was due to forest denudation.

11. As regards the question, as to what evidence there was that the catchment areas had been denuded to any serious extent during the preceding half century :—The Government of Madras found it difficult to give a decisive answer on this point, owing to the scanty information available. Forest reservation had not commenced in Madras half a century ago and the absence of observers closely interested in the subject had led to an absence of adequate records. There was a great deal of evidence to show that there had been some serious amount of denudation, during the last 25 years, in the hill tracts of Parlakimedi, attributable to the system of shifting cultivation carried on by the hillmen and to their increasing numbers. The Parlakimedi Maliahs were not, however, within the catchment area of any important streams. Reports had also reached that Government of some amount of denudation having occurred in the hill tracts of Vizagapatam, but this had taken place, if at all, in zamindari areas, over which the existing law gives the Government no powers of control.

As regards Bombay, it was well known that denudation had taken place rapidly until measures of forest conservancy were taken. These had been steadily pursued for some 50 years, and with increased intensity during the last 30 years.

In Bengal, the Committee appointed to consider the question of denudation of forests had dealt at some length with the extent and probable progress of forest denudation in Chota Nagpur, Orissa and the Feudatory States. With the conclusions at which they arrived the Lieutenant-Governor was generally in accord. He considered the fact established that denudation, though it commenced very long ago, had in recent years progressed at a rapidly increasing and now alarming rate, and also that the destruction of forests had been wasteful in the extreme, and had proceeded without forethought or any provision for regeneration. The Committee were disposed to hold the Settlement Department responsible for having in some degree accelerated this process. This conclusion, as regards any deliberate, or indeed any avoidable, action of the Department, was not accepted but it was thought certain that, under existing circumstances, the progress of denudation would continue with increasing velocity. The extension of communications, the

increase of population, the contraction of the surplus supply of timber, and the emancipation of the raiyats were causes of certain operation. Since natural regeneration was effectually prevented by excessive grazing and by seasonal burning, each piece of forest cleared meant a diminished supply and a more rapid exhaustion of the reserves. This would be the case even were the demand to remain stationary, but since it yearly increased the progress of denudation was constantly accelerated. Added to these general causes, there were, especially in Chota Nagpur, contributory factors, such as the general ignorance of all principles of forestry, the apathy and impecuniosity of the zamindars, who were unable to appreciate the real merits of any bargain which promised ready money, and also their powerlessness to control their still more improvident aboriginal raiyats. As the Committee had remarked, wasteful cutting by the villagers themselves is even more detrimental to forests than the operations of contractors. Contractors might cut down jungles, but they did not exterminate them or prevent their regeneration. This the villagers did by rooting up stumps of trees, by "jhuming," by grazing their cattle on the young growth and by firing the hillsides, in order that their fields below might be benefitted by the ashes which are washed down by the rains. Forest fires in the unprotected jungles of Chota Nagpur were neither incidents nor accidents, but a general feature of the early hot weather when at night every hillside might be seen traversed by lines of fire. Under these circumstances, there could be no hope of regeneration, and it might be taken as certain that in the absence of any definite policy of conservation, Chota Nagpur and many parts of Orissa would, to the irreparable ruin of their prosperity, at no distant date be stripped of all growth except worthless shrubs.

In the opinion of the Government of the United Provinces, there was no doubt that the third class or village forests, which are neither preserved nor protected, were until very recent years steadily disappearing in the hills, and especially the oak forests in the vicinity of villages, where they are subjected to heavy lopping. The process, though steady, was said to be slow, and, in the absence of any definite records of the original extent of such forests, it was found impossible to say how much had been denuded in this way. Plantation, it was said, was now being undertaken to counteract this denudation. Again, a report recently prepared on the forests of the Tehri-Gārhwal State showed that the oak forests, which occupy a very large proportion of the total area under forest in that State, were being steadily encroached upon and would eventually disappear if steps were not taken to check the process. It was found impossible to make even a rough estimate of the extent to which such forest had been denuded in the past 50 years, but

from their present condition in which all stages down to that verging on extinction were represented, it was clear that considerable areas of oak forest must have already ceased to exist as such.

In the Punjab, as already shown, there had been denudation in parts of the outer Himalayas, in the Siwaliks, the Salt Range, the Pabbi and other low hills of the Province and it was going on at present in the Kangra District. In the vicinity of Simla, where there were formerly large areas of oak and pine forests, in the hills between Simla and the plains, and also between Simla and Phagu, there had been considerable denudation of forests for the purposes of potato cultivation.

In Burma, a great deal of denudation of forest growth had occurred in consequence of the widespread practice of shifting cultivation in the hills. In many cases, as in Assam, a quick growth of rank vegetation tended to reduce the damage done, in some cases, however, as in the hills east of Bhamo, bordering on the Chinese frontier and in parts of the Southern Shan States, the hills remained almost completely bare; a typical example of the serious damage which resulted from unrestricted shifting cultivation was the Myelat Plateau in the Southern Shan States. This large tract of country was once undoubtedly well-wooded with pine and oak forests; but a long course of *taungya* cultivation, carried on for the last century or so, had almost completely exterminated the pine woods on the plateau and only a few small isolated clumps remained. This conifer, as usual with trees of that family, was unable to regenerate itself by means of coppice shoots, and as a consequence *taungya* cultivation on areas covered with pine-meant the absolute extermination of the latter. When the pine began to get scarce, the inhabitants had to turn to the comparatively small areas covered with oaks and other species for timber and fuel, the latter, specially, being in great demand on the cold windswept plateau; but the demand being greater than the supply these small forests of broad-leaved species were in their turn exterminated with the result that nine-tenths of the plateau now consisted of bare open downs covered with short grass and bracken fern. As a consequence the water-supply had become scarce and the soil no longer had the power to hold large supplies of moisture and so to regulate the flow of water in the streams. During the rainy season the latter were subject to very sudden and violent floods which subsided as quickly as they rose and the water flowed either into the large Inle Lake or down to the plains of Burma, leaving the beds of the streams almost dry. The country was also cut up, as a result of these violent floods, by very deep ravines, having vertical banks, similar in character to the canons found in the arid parts of North America. The soil on the plateau was a marvellously rich one and with a good water-supply the value and

extent of the crops would increase tenfold. Fortunately for the inhabitants of this part of the country, the forests on some of the higher hills bordering the west end of the plateau had not all been destroyed, and a few streams that took their rise on these hills still flowed down to the bare open downs and watered the country to a certain extent.

As another case of deforestation on a large scale that had taken place within recent years the following was quoted :—Several hundred square miles in the Zawgyi catchment area had been converted from pine and high evergreen forest into treeless grass-land and Settlement proceedings elicited the fact that the majority of the Palaung Settlements responsible for this deforestation were established in this locality within the last 50 years.

From the evidence obtained in the Central Provinces it did not appear that catchment areas had been denuded to any serious extent during the preceding half century.

12. With reference to the question as to *what steps had been taken to check the destruction of forest vegetation, and the effect of such measures in preventing denudation of catchment areas, and in maintaining an equable distribution of the available moisture* :—Generally speaking, it may be said that the reservation of forests has been the most important step taken. Areas which it has been considered desirable to keep under forest, whether for climatic or other reasons, have been selected from time to time and formed into reserved forests. Many of these areas have been selected on purpose to prevent the denudation of catchment areas and within recent years 2,000 square miles of forests have been constituted reserves for reasons at least partially climatic, in Burma alone—whilst a further area of 3,700 square miles has been proposed for reservation in the same province for similar reasons. Other areas, over which, in the interests of the people, a less strict protection was considered necessary, have been formed into protected forests. The forest waste lands at the disposal of Government, from which reserved and protected forests are gradually selected, are also under a certain amount of protection by rules framed by the Local Governments. A number of Forest Acts have been passed, and reserved and protected forests may be said to be efficiently protected by the various Forest Laws.

The progress of reservation during the past years and the proportion of forest lands under the management of the Forest Department to the total area of the Indian Empire may be gauged by an examination of the table on pages 5 and 6, which shows the area of forest lands under the management of the Forest Department at the close of the Forest year 1912-13. Up to the 1st July 1913, an area of 96,867 square miles has been formed into reserved forests, and 8,492 square miles into protected

forests. There is still an area of 1,33,564 square miles of unclassed forests, the greater part of which is in Burma and in Eastern Bengal and Assam, and much of this will gradually be formed into reserved forests. The area under the control of the Forest Department amounts to 22·1 per cent of the area of British India, and were these forest lands equally distributed, it might be considered sufficient to regulate and control the water-supply. Unfortunately this is not the case, as pointed out in paragraph 6 above.

For a considerable proportion of the reserved forests, working-plans regulating the yield and ensuring the permanence of the forest have been prepared, though much still remains to be done in this direction.

Consistent measures are taken in all Provinces to preserve the reserved forests from fire. During the year 1912-13, 51,659 square miles of reserves were under protection, out of a total of 96,867 square miles for reserved forests.

Apart from the measures of regular forest conservancy resulting in the formation of reserved and protected forests under the protection of the Forest Department and of the Forest Laws, much has been done by Local Governments under executive orders. One of the most difficult problems is the management, and regulation of shifting* cultivation,

* Taungya in Burma.

Kumri in Assam.

Jhuming in North-Western Provinces.

Dhaiya in Central Provinces.

vigation, a most destructive practice by which large areas of valuable forest have been destroyed by the wild tribes, but which in many cases forms their only means of subsistence. The subject has

attracted considerable attention for many years past, and in the more advanced provinces, as for instance, the United Provinces, the practice has been practically put a stop to. In the less developed provinces, where there are still vast tracts of virgin forest and the pressure of the population on the soil has not yet made itself felt, as in Burma and Eastern Bengal and Assam, the practice still continues and is the cause of much denudation of forest growth. Attention is being paid to this matter and the evil results of this destructive practice are recognized and are being combated as far as possible. In Native States and over private forests the matter is often on a very unsatisfactory footing.

In certain provinces, particularly in the Punjab and the North-West Frontier Province, much attention is being paid to the protection of village forests and special rules have been framed in this direction. The measures taken have resulted in satisfactory improvement in the conditions of these forests, which are of considerable extent and importance in these provinces.

In certain areas, not entirely at the disposal of Government, where the want of forest conservancy measures has resulted in manifest damage and injury to surrounding lands, special measures have been taken and special legislation undertaken to put matters on a better footing. The Hoshiarpur Chos in the Punjab is a case in point, where, owing to denudation of the growth and excessive grazing on the unstable hillsides of the Siwaliks, extensive erosion took place, and the sub-lying cultivated lands were rendered useless over a large area by the deposits of sand, silt and boulders brought down by the torrents from the denuded hills above. The results of the measures taken, *viz.*, closure from timber cutting and from fire and grazing, are encouraging. The evils resulting from denudation of forest growth are clearly demonstrated in this particular case, and from the experience gained during the past ten years, since special legislation and ordinary forest conservancy measures have been in force, it is practically certain that with the re-afforestation of the area affected the evils will disappear.

Many important forest areas are to be found in the various Native States and where these occur in the hills their preservation is of the highest importance. In some cases, as in Chamba, Jubal, Bashahr, the Simla Hill States, and the Northern and Southern Shan States, the forests are under the direct management of the Forest Department. In most cases, however, the management is left to the States, in many of which a Forest

- * Jammu and Kashmir.
- Mysore.
- Indore.
- Nizam's Dominions.
- Bhopawar Agency.
- Travancore.
- Jaipur State.
- Cochin.
- Gwalior.
- Baroda.
- Alwar.
- Rewah.

Department has been organized. Much progress has been made in this direction and in many Native States the forests are under regular management.* In some cases, as in Kashmir and Chamba, the Government of India lend Imperial Forest officers to take charge of the forests. In many others, officers of the Provincial Forest Service have been deputed to strengthen the local Forest Departments.

Native States are sending students in increasing numbers to be trained at the Forest College at Dehra, and satisfactory (though slow) progress is being made in the appreciation and application of correct principles of forest management in the Native States. It is certain, however, that much still remains to be done in this direction.

The Local Governments in replying to this question pointed out as follows :—

It was stated that in Madras the reserves already constituted amounted, on the 30th June 1907,† to 18,541 square miles including 253

† The general enquiry was started in 1906, *vide* paragraph 1.

square miles added in the year 1906-07 and that a further area of 659 square miles had been notified to be reserved. Excluding zamindari areas and inams, the area of reserved forests was equal to 22·53 per cent. of the total area of the Presidency and no great further extension of forest reserves was called for or practicable.

In Bombay about 15,000 square miles had been placed under management as forests. The areas had been selected with special regard, *inter alia*, to the protection from denudation of the headwaters and banks of rivers and streams. Large areas had been classed as forest proper, though not as yet productive as forests, on the express ground of the necessity of protecting them from denudation. The denudation, which was in progress before forest reservation began, has thus been checked.

In recent years in Bengal, much had been done to check the destruction of forest vegetation in states wholly or partially controlled by Government. Considerable areas had been demarcated and declared protected in the Porahat and Kolhan estates of Singhblum. Proposals for the creation of protected forests in the Sambalpur District had been accepted. Similar action had been taken in the Singhblum District and an enquiry into the possibility of forest protection in the Khondmals of Orissa was in progress.

It was pointed out that the amount of land in Bengal over which Government had control was very small, of the total area occupied by Government forests of all kinds, more than half consisted of the Sundarban jungles. In the places which naturally contain most forests, the possessions of Government were extremely limited. In Chota Nagpur, for instance, there had been reservation of any extent only in Palanau and Singhblum, whereas the evidence collected by the Committee showed that denudation had been most severe and complete in the central districts of this division, which still contain much jungle, and in recent times were almost covered by forest, but in which the Government forests were almost negligible. Unless, therefore, some new system of conservation could be adopted, it was considered probable that within the next half century all privately-owned forests worthy of the name will have disappeared from Chota Nagpur and Orissa.

Measures were, however, being undertaken to remedy this unsatisfactory state of affairs in order to check denudation and to preserve and improve the still existing private forests.

Reference was made by the Government of the United Provinces to the reservation under the officers of the Forest Department of some 4,000 square miles of State forest and the protection afforded under the Forest

Act to an area exceeding 9,000 square miles of protected forest, most of the former being under fire-conservancy. It was remarked that the results of the above protection were no doubt beneficial, but as they were mostly negative they were incapable of demonstration. It was pointed out that there was not the slightest doubt that had these forests not been placed in charge of the Forest Department and strictly preserved, they would by this time have been denuded of all marketable timber, and the more accessible and fertile areas would have been ruined by the admission of temporary or permanent cultivation. The action of Government, however, so far as the present question was concerned, had, it was said, been purely protective : there has been little creation of new forest, and no instance of such creation outside the Forest Department's boundaries. There was a large area also of protected forest in Kumaun under the management of the District officers which had not perhaps always received the attention they deserve, but the question of the improvement of their constitution and management had, for some time, been engaging the attention of the Local Government.

The following concise description of the steps which had been taken in the Punjab to check the destruction of forest vegetation was given :—

(i) The legal position of all forests has been placed on a satisfactory basis, except in so far as many of them are under provisions of Chapter IV of the Forest Act, instead of Chapter II.

(ii) Working-plans had been made for nearly all the important forests, thus bringing the management into as satisfactory a state as was reasonably possible, having regard to (a) the present limited knowledge of sylviculture as applied to Indian species, and (b) the fact that, speaking generally, an efficient protective establishment to carry out the provisions of the plans had not been provided.

~~(iii)~~ No serious measures for afforesting bare areas in the hills had been taken nor could any such be inaugurated until the abuse of existing rights of user had been checked.

(iv) Afforestation in the plains had been successfully undertaken on an area of 10,000 acres in Changa Manga, and active steps were in progress towards dealing similarly with further areas aggregating 90,000 acres.

(v) Protection of the forest areas from fire was organized in a manner which would probably be sufficient if any real sustained protection from excessive grazing and grass-cutting were possible, which it was not in consequence of the rights of user dependent on the forests.

It was considered in Burma that the enquiry had neither established on sufficient or satisfactory evidence any new facts, nor furnished confirmation of existing hypotheses or theories, nor in the nature of things could it be expected to do so. But the Local Government had, for some years, proceeded on the assumption that forest preservation was desirable or even necessary, in the interests of the rainfall and a good deal of practical work had been done in that direction and for that purpose. Since 1897, over 2,000 square miles of reserves had been constituted, in whole or in part for climatic purposes and over 3,700 were proposed to be constituted reserved forest for reasons at least partially climatic. Apart from action directed to reservation, measures had been taken for the restriction of *taungya* cutting, and considerable protection had been afforded, over large areas at the head-waters of streams, to prevent denudation. The measures were, however, of too recent date to permit of their full effects yet being estimated.

In Eastern Bengal and Assam, it was observed that the creation of reserved forests was the most important action yet taken. In 1882, the area of reserved forests throughout the province, including the Eastern Bengal districts, was 4,162 square miles ; in 1907, it had increased to 6,560 square miles. The effect of reservation in certain hill districts had undoubtedly been beneficial in protecting the catchment areas of rivers and streams.

Apart from a rule affecting private forests in the Central Provinces, very little action, with the express object of maintaining an equitable distribution of moisture, had been taken hitherto. But the need to maintain and preserve reserved forests in the interests of the people had, it was said, sufficed on the whole to check disforestation of Government forests and had attained the desired object. As regards private forests, it was remarked that rules existed to check wanton cutting, and these rules had, in the main, attained their purpose.

In Baluchistan, the steps taken to check the destruction of ~~forest~~ vegetation included the constitution of considerable areas as reserved forests and outside these areas the prohibition of unauthorized cutting of forest trees growing on land at the disposal of Government. These measures had checked the denudation of important catchment areas, but the area, in which forest vegetation existed, was so minute in relation to the total area of the country and the forest growth in such areas so sparse and scattered, that it was unlikely that any very considerable effect has been produced in regard to the equitable distribution of the available moisture.

The replies of Local Governments show that denudation, which was in progress before forest reservation had begun, has been checked, and as a matter

of fact, much of the catchment areas of many of our important rivers have been formed into either reserved or protected forests. The protection of such catchment areas is, however, by no means complete, and where these lie in Native States or in private lands it is certain that much regrettable denudation has taken, and is taking, place.

As to what the effects of the measures taken had been in maintaining an equitable distribution of the available moisture, Local Governments agreed that they were incapable of demonstration.

Experience in all parts of the world conclusively proves that extensive clearing on hill sides, more particularly when these take the form of shifting cultivation, are followed by disastrous consequences, such as landslips, violent floods in the rivers, the washing away of all cultivable soil and the silting up of rivers, the destruction of arable land and the drying up of streams. There is much evidence in the present enquiry to show that what has been found true in other countries is equally true in India, and that the generally satisfactory nature of the evidence which has been elicited may be regarded as a very complete justification on these grounds alone, of the wisdom of the Government of India's forest policy during the past 50 years in gradually extending the areas of reserved forests and in generally protecting forest growth where this can be done without injury to more important interests, and in the maintenance of a professional Forest Department. Had not this policy been kept consistently in force, the results of the present enquiry would have indeed been very different.

13. The last question for consideration was *whether sufficient ground existed for taking further measures to check the destruction of forests or to re-forest areas which had been denuded of their forest growth, and if so, what measures were recommended.* It was agreed generally in all the Provinces that the measures of Forest Conservancy which had been adopted, during the preceding 50 years, had in most Provinces resulted in the preservation of a sufficient area of forests, so that no widespread damage, arising from the destruction of forest growth, had occurred.

In Bombay, Madras, the Central Provinces and the Punjab, there appeared to be no scope for any special action, beyond proceeding on the lines of the policy already adopted. In the latter province it was intended to encourage arboriculture by local bodies on the lines already pursued, and to deal with the problem of denudation, caused by excessive grazing in the Kangra District, the Siwaliks, the Salt Range and other low hills; the extension of the Chos Act to the Umballa and Karnal districts was contemplated, as also steps to afforest the western slopes of the Pabba Range.

In Burma, the examination of localities, especially in the catchment area of streams, or where the forest was believed to be valuable from the climatic standpoint, was to be undertaken, as also further reservation of forest where that was practicable, and the prohibition or restriction of shifting cultivation and the regulation and reduction, if possible, of the grazing and breeding of goats. The rules regarding the prohibition of felling of trees in the vicinity of roads and streams were to be given more effect to.

In Eastern Bengal and Assam, the desirability of inducing the hill tribes to adopt permanent, in place of shifting cultivation, was recognised, though at the same time it was pointed out that it would take many years to change the customs of centuries.

The measures required to stop the destruction of forests in the North-West Frontier Province were under consideration.

In Bengal, the ill effects that had followed the destruction of forests, more particularly in Chota Nagpur and Orissa, were emphasised. The bulk of the unprotected forest left in Chota Nagpur, and indeed almost throughout the province, was on hills or other ground unsuitable for any form of permanent cultivation. The preservation of large tracts of jungle, at least in Chota Nagpur and Orissa, was considered an administrative necessity, and steps were already being taken to provide by legislation for the restrictions which it was considered necessary should be enforced in regard to privately owned forests. Reference was made to the importance of protecting Himalayan forests along the northern boundary of Bengal.

In the United Provinces it was thought that possibly much might be done in regard to the afforestation of waste lands ; in addition to the physical effects of forests so created, a supply of fuel, fodder and timber for agricultural purposes would be obtained. [It may be mentioned that since the Local Government submitted its report on the questions raised, a vigorous policy of afforestation has been pursued in the United Provinces.]

After a careful examination of the replies received from Local Governments, as summarized above, and after consultation with the Director-General of Observatories, the conclusions arrived at by the Government of India were briefly that the influence of forest on rainfall was probably small, but that the depudation of the soil, owing to the destruction of forests, might, as far as India is concerned, be looked upon as an established fact, while as regards the effect of forest preservation on rainfall and the underground water-supply, the papers forwarded did not provide sufficient information to justify any change in the principles on which the forest

policy of the Government has hitherto been based. It was remarked that these principles were founded mainly on consideration of a directly economic character, connected with the conservation of the grazing resources and forest produce of the country, and that the climatological considerations did not in any way affect these well-established principles.

At the same time it was thought, that if there was any reasonable prospect of fresh and accurate data being obtained, a few experiments might usefully be initiated in a small number of selected localities and the Local Governments were accordingly *again addressed* in the matter. The points on which information was considered desirable were :—

- (i) the local differences in the rainfall, temperature, and humidity inside and outside forest areas;
- (ii) the local differences in the level of the underground water-table in areas near to, and far from, forest land, respectively;
- (iii) the local differences in the height and duration of floods after similar amounts, and durations of rainfall in channels fed from forest and non-forest areas, respectively.

A report was therefore asked for, showing the places in each forest circle which were considered suitable for such experiments, together with suggestions as to the manner in which they should be carried out and the agency which should be employed in conducting them.

In addition to these enquiries it was suggested that, if opportunity occurred, observations should be made regarding the influence upon the average rainfall, over a large tract of country, of a material change in the area of forests within it.

Local Governments were also desired to pass briefly in review the more important catchment areas of torrents, streams, or rivers affecting cultivation within their respective jurisdictions and to consider whether special action of any kind, such as stricter conservation or even in some cases reforestation, is advisable for the purpose of preventing the denudation of lands affected, due regard being paid in every case to the relative interests of the population living in the neighbourhood of the forests, and of the distant agricultural population dependent on an equitable distribution of the water-supply.

The replies from all Local Governments and Administrations having been received, they were considered in consultation with the Board of Scientific Advice, and the decision of the Government of India on the points enumerated above were as follows :—

- (i) Meteorological stations established in suitable localities at which observations to show the local differences in the rainfall, temperature, and humidity inside and outside forest areas, would be recorded would probably yield

valuable results and if it be found possible to initiate enquiries of this nature further action would be taken.

(ii) It was considered that experiments or observations, intended to ascertain the local differences in the level of the underground water-table, need not be initiated. Such differences are due to a variety of causes and any data that might be obtained, would be of little value in determining to what extent forests affected the level of the underground water-table.

(iii) It did not appear from the information supplied that satisfactory experiments could be undertaken to ascertain local differences in the height and duration of floods in channels fed from forest, and non-forest areas, respectively, after similar amounts and duration of rainfall. The belief that denudation is harmful in its effects is confident and almost universal and there could be no doubt that forests, by controlling the run-off of precipitation, and by lessening the chance of disastrous floods, were beneficial.

(iv) No material change in the forest area within any province appeared to be contemplated, but the Government of India desired that Local Governments would bear in mind the suggestion, that, if opportunity occurs, observations should be made to ascertain the effect on the average rainfall of any considerable change in the forest area.

(v) As regards the question whether, after review of the more important catchment areas, special action of any kind such as stricter conservation or reafforestation was necessary, it appeared that the subject had received careful consideration in the past, and that suitable action had been taken in cases where this has been found to be necessary. The replies received indicated that in the Central Provinces, Burma, the North-West Frontier Province, the Andamans, Baluchistan, Ajmer and Coorg, no special action was required so far, at least, as Government forests are concerned, while in other Provinces the matter would continue to receive careful attention. In view of the great importance of taking adequate measures to prevent denudation, the Government of India hoped that, in addition to such measures as it might be found necessary to carry out from time to time in Government lands, every effort would be made to induce rulers of Native States and owners of private land to take similar action. In some parts of India

the wasteful and injurious practice of shifting cultivation was still common in forests which are included in important catchment areas, and although political considerations may in many cases render it difficult to restrict this practice at present, the Government of India desired that the advisability, and indeed the necessity, of its regulation should be steadily borne in mind.

It was recognized that the enquiries instituted so long ago as 1907, had entailed on Local Governments and their officers a considerable amount of labour, and the Government of India expressed their appreciation for the valuable and interesting information that had been supplied. The enquiry had gone far to show that the main principles hitherto adopted in regard to forest conservation were suitable and efficacious ; it had served the purpose of calling attention to the importance of forests to the well-being of the country at large ; it had shown that no hasty action was called for ; and if, at any time, it became necessary to take definite action where damage had been proved, the information which had been collected would be found to be of great value.

APPENDIX I.

Report on the evidence from meteorological records of any apparently permanent change in the amount and distribution of the rainfall over the different large areas of India, and on the probable causes of such changes, if and where they have taken place, by Dr. Walker, M.A., F.R.S., Director-General of Observatories in India.

Before considering the numerical results obtained by computing the rainfall data of the different portions of the country, it is necessary to consider both the reliability of the records and the number of years over which measurements must extend in order that it may be possible to decide whether any changes observed may be classed as permanent.

Prior to 1890 the rain-gauges in use were of different patterns, some fairly accurate and some inaccurate, and even where the Symon's rain-gauge, which has since been adopted as the standard, was employed, large errors were introduced in a number of cases by using with it a measure glass of the wrong size. In the United Provinces, the Punjab, and probably in Bombay, except at regular observatories, the recognized instrument was a float gauge of very defective design which invariably registered less than the correct amount. The inaccuracies due to defective appliances were frequently supplemented by errors due to inattention in the selection of sites, rain-gauges being placed under trees or in close proximity to buildings; and in some cases, instead of the instruments being vertical, they were inclined at a considerable angle. But important as the errors due to these sources must have been, it is probable that they were not so serious as those due to carelessness on the part of the observers; and in his memoir of 1886 on the

Indian Meteorological Memoirs, Volume III, Part I, page 3. "Rainfall" of India Mr. Blanford said of the records of stations which he had picked out for their reliability:—

"The data thus selected cannot of course pretend, as a whole, to a high degree of accuracy. But were we to reject all but those the accuracy of which is guaranteed by the conditions of observation, we should have to throw aside nearly all that relates to years anterior to 1864 or 1865, and indeed a considerable part of the later records."

For a more detailed account of the earlier methods of measurement

Pages 2 and 3.

No. 520-S., dated Simla, the 5th October 1889, to the Secretary to the Government of India, Department of Revenue and Agriculture.

reference may be made to Blanford's memoir above referred to, to its postscript, and to the letter in which my predecessor submitted proposals for the organization of rainfall registration throughout India.

These impressions are confirmed by a study of the earlier records. Taking for years before 1891 the data of Blanford's selected stations and after that date the complete information of the 2,500 stations, the departure from normal of the rainfall of India during the monsoon period, June to September, has been tabulated for the years 1841 up to date. The result is shown in Figure 1 at the end of this report and the figures in Table I of the Appendix.* It will be seen that the deficiency of precipitation during the period of 18 years from 1843 to 1860, if it had really been as indicated, would have been known historically as disastrous. A failure is shown in 1855 as bad as that of 1877 or 1899 and that of 1848 as even worse ; while the indications of six other years are as bad as that of 1901. In 1848 the number of rain-gauges included is 75, and in 1856, 29. If we turn to the report of the Indian Famine Commission (pages 21-22), we find that between 1823 and 1877 there are fourteen years of drought or scarcity, and only three of these occur between 1813 and 1880 ; while neither 1855 nor 1848 is among the three, which are 1814, 1853 and 1860. The early rainfall records are not thus supported by historical evidence. Again there are meteorological relations between rainfall and several other climatic features which hold with tolerable uniformity in the later but are violated in the earlier years. It appears therefore inevitable that the data previous to about 1865 should be regarded as unreliable ; and although a part of the deficiency of rainfall shown in the early records may be due to the use of a float gauge, there is no information as to how much allowance should be made for the fact, and the data cannot be trusted for present purposes.

It should be pointed out that although the previous remarks condemn the early results derived from the ordinary rain-gauges they do not apply to those of the long-established observatories of Madras, Bombay and Calcutta, where it may be assumed that trustworthy measurements have been made for many years. At Madras the mean annual rainfall of the past thirty years has been 49.51 inches, while that of the previous 65 years was 48.79 inches ; at Bombay (Colaba) the mean of the past 30 years has been 72.71 inches, while that of the previous 31 years was 70.21 inches ; and at Calcutta the average of the past 30 years has been 62.69 inches, while that of the previous 48 years was 66.23 inches.

The question of the criteria to be employed before any changes of climate can be regarded as permanent has next to be considered. Of the countries affected by the monsoon the only area for which reliable

* The table and diagrams referred to in this report are not reproduced here. They may be found in Part I, Volume XXI, of the Memoirs of the Indian Meteorological Department.

data extend over a satisfactorily long period is Egypt, where the Nile data extend back as far as 1737 except for a break from 1801 to 1824 : of these records the series of 83 years from 1828 is known to be very fairly accurate since there were for almost every year at least two gauges which were simultaneously recording the river levels. Inasmuch as the Nile flood is determined * by the monsoon rainfall of Abyssinia, and as the moist winds which provide this rainfall travel in the earlier portion of their movement side by side with those which ultimately reach the north of the Arabian Sea, there is a tolerably close correspondence between the abundance of the Nile flood and that of the monsoon rains of North-West India ; the numerical data of this area will be found in Table 2 and the correspondence will be seen by comparing the successive years in the curves of Figures 2 and 3. It would thus appear legitimate to utilize the Nile data for indicating, at any rate, approximately the character of the variations to which the Indian monsoon is liable. An examination of the curve of Figure 2 will show that there have been fairly long periods of deficiency followed by complete recovery. Thus in the 17 years from 1781 to 1797 the Nile is shown as below normal in every year with one exception, and there is a series of 15 years from 1825 to 1839 all of which, except two, were in defect : the average flood of the 15 years was 8 per cent. below normal. These facts prove, in my opinion, that a shortage of rain cannot be regarded as indicating a permanent change of climate unless it extends over thirty years at the very least. The means for the last thirty years of the first class observatories cannot be quoted in favour of a permanent change ; and apart from these the number of years for which reliable data exist is unhappily only about forty, so that even if the last twenty years were to differ materially from the first twenty it would not be sufficient to establish a permanent change.

In view of the widespread impression that there has been a change of climate in North-West India it is of some importance to ascertain to how great an extent this view is supported by the data. Tabulations have accordingly been effected of the rainfall of each province, beginning at the earliest year for which a satisfactory number of stations are available and ending at 1907 ; and records of the same stations have been considered throughout the period in order to avoid introducing fortuitous changes into the rainfall of the province by adding stations whose normal rainfall may have differed from that of the stations already employed.

* Since this report was written it has been maintained that the Nile is largely fed by humid currents that have crossed Africa from the South-west ; but the argument regarding the permanency of change is scarcely affected.

In the case of the Punjab, with which the North-West Frontier Province has been included, diagrams and figures are given below for the whole year (Figure 6), the cold weather period December to February (Figure 7), the hot weather period March to June (Figure 8), and the rains from July to September (Figure 9). The years examined are the 45 years rains from 1863 to 1907, and numerical data are contained in Table III. Taking the first 22 years the mean annual rainfall is 21.24 inches, that of the cold weather is 2.57 inches, of the hot weather 4.50 inches and of the monsoon 13.65 inches, for the last 22 years the corresponding means have been 20.17 inches, 3.06 inches, 4.00 inches, and 12.82 inches, respectively. Thus while the annual rainfall has decreased by 5 per cent., that of the cold weather has increased by 19 per cent., that of the hot weather is smaller by 11 per cent., and that of the monsoon smaller by 6 per cent. Inspection of Figure 6 will show that there is little to suggest a gradual climatic change; the amount of rain increased to a maximum in 1893, 1894, then fell suddenly and has been increasing again since 1899.

In Rajputana, the data of the 34 years from 1874 to date again show a diminution except in the cold weather: the rainfall of the year has, estimated from 15 years' averages, decreased in the interval from 26.42 inches to 22.81 inches, that of the hot weather from 0.77 inch to 0.71 inch and of the monsoon (June to September) from 21.31 inches to 20.97 inches, while the cold weather rainfall has increased very slightly from 0.76 inch to 0.79 inch. The manner in which the changes have occurred resembles closely that of the Punjab except that it has not improved appreciably of late: see Figures 10 to 13 and Table IV.

The data for Gujarat lead to results like those of the Punjab and Rajputana. They cover 36 years and during that interval there has been a decrease in the fifteen-year means of annual rainfall from 35.32 inches to 29.92 inches, of hot weather rain from 0.88 inch to 0.23 inch and of monsoon rain (June to October) from 34.64 inches to 29.22 inches. The diminution of 15 per cent in the annual rainfall is large, but as in the case of the Punjab there was a rise to 1894 followed by a fall to 1899 and since then there has been a marked improvement as shown by Figure 14. The numerical data will be found in Table V.

In the case of the United Provinces, sufficient data are available from 1845 to 1854 and from 1861 to 1907. Here a comparison of the first twenty years and the last twenty shows an increase in the monsoon rains (June to October) from 32.23 inches to 34.79 inches, of the cold weather rain from 1.75 inches to 2.23 inches, of the annual rain from 35.57 inches to 38.32 inches, the hot weather rain has diminished from 1.42

inches to 1·10 inches. It appears probable that the increase is in part accounted for by the use in the earlier years of float gauges, but it is very doubtful whether this is sufficient to explain the whole effect. The curves are in Figures 17 to 20 and the data in Table VI.

In Central India West, Figures 21 to 24 show less approximation to the history of Rajputana than might have been anticipated : there has been since 1887 a slow diminution in monsoon rainfall with a recent tendency towards improvement. See Table VII. In Central India East (Figures 25 to 28 and Table VIII), there is indicated a slight falling-off in the monsoon since the maximum of 1894.

In the Central Provinces, data have been utilized from 1845 to 1849 and 1866 to 1907. Here the averages for the first twenty available years and the last twenty are practically identical. The curves (Figures 29 to 31) show that from 1877 to 1881 there was a rapid rise in the quantity of precipitation, but that from 1891 to 1903 there was an equally rapid fall, and it certainly cannot be said that there has been any persistent change during the past thirty years. The rain of the hot weather period, March to May, does not show any marked features. See Table IX.

The annual rainfall data of Bombay (excluding Sind and Gujarat) have been tabulated from 1862 up to date and show a falling-off from 1892 to 1899 with practically no recovery since then. On the whole the diminution during the period available has been appreciable but not large.

In the cases of Hyderabad, Mysore, Madras, Bengal, Eastern Bengal and Assam, and Burma, the annual rainfalls show no appreciable signs of climatic change. See Figures 32 to 38 and Tables X to XVI.

Summing up, it may be said that, although there is no proof of any permanent climatic change, there has been a tendency over a large part of North-West India for rainfall during the past twenty years—

- (a) to increase to a maximum between 1892 and 1894 ;
- (b) to sink to a minimum in 1899 ; and
- (c) to improve very slowly since that time.

The tendencies (a) and (b) are shown clearly in the Punjab, Rajputana and Gujarat and partially in the United Provinces, Central India, the Central Provinces and Bombay. The tendency (c) is shown only in the Punjab, Gujarat and Central India West ; in Rajputana, the United Provinces, Central India East, the Central Provinces and Bombay there has been no appreciable inclination to improve during the last few years. Over the remainder of India there do not appear to have been any progressive changes of importance.

When seeking an explanation of these changes the opposite characters of the tendencies (a) and (b) appear to negative any explanation in terms

of a factor of steadily increasing importance such as the increase of irrigation. The direct influence of forests upon rainfall is, I believe, almost universally regarded by specialists as small ; and although the information at my disposal regarding the destruction and re-establishment of forests is extremely scanty, it would suggest that destruction on a fairly large scale was in vogue some fifty years ago, and that during the past twenty years a material improvement had taken place. The effect of this would, however, have been a relatively low rainfall forty to fifty years ago and there would have been a gradual improvement during the past fifteen or twenty years—a result entirely different from that observed.

One other explanation has still to be considered. A statistical examination of the data of the monsoon rainfall and the temperature and pressure of India in May shows that these Indian conditions have no perceptible influence ; but conditions in the South Indian Ocean, where the monsoon winds take their origin, and in the sub-equatorial region, have a considerable effect. It would, therefore, seem natural to ascertain whether the tendencies in question have not been associated with abnormal features south of the equator. And as the changes in India are confined to the northern half of the field of the Arabian Sea current, it would seem natural if this cause be the true one to expect corresponding changes in Abyssinian rainfall and in the height of the Nile. An examination of the proportions of Figures 2 and 3, corresponding to the period 1888 to 1907, will show a striking similarity in the general tendencies, and this is perhaps more easily seen in Figures 4 and 5 in which the irregularities from year to year are smoothed out by plotting for any year the mean of the five years of which it is the centre. In the Nile, as in North-West India, there was a rise to a maximum in 1894 followed by a rapid fall to 1899, since which time a marked deficiency has prevailed. This latter period has been associated with abnormally heavy rain at Zanzibar in May, and hence with an unusually large ascensional movement at the Equator. Whatever be the ultimate physical cause, I consider that the changes in North-West India must be attributed to something abnormal in the large movements of the atmosphere, and not to human agency in India.

APPENDIX II.

Note on the effect of forests on rainfall by Dr. Walker, M.A., F.R.S.

"For an authoritative summary of the results of European and American observations upon the influence of forests, upon air temperature, ground temperature, humidity, rainfall, the run-off and the strength

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of the wind reference may be made to the *Handbuch der Klimatologie* (Volume I, pages 186-193, 1908) by Dr. J. Hann, the greatest authority on climatology. The effects are in all cases small ; in a forest both the air and the ground are cooler than outside the forest by something like 2°F., the percentage of saturation of the air by water-vapour is greater by about 10, and mist condenses freely on the trees. As regards rainfall, the amount falling inside the forest appears in Germany to be about 3 per cent. larger than that outside. This does not, however, prove that the rainfall outside has been increased, and it is outside that it is needed for the growing of crops.

There are reasons, however, for thinking that in the tropics the influence of forests may perhaps be greater. There the drying influence of the sun is more powerful, and the shade of the trees might be expected to have more effect ; also during the monsoon when the air is almost saturated the greater humidity and coolness over a forest might occasionally start the condensation of the vapour, and when this has been started it would continue automatically like an explosion of gunpowder to which a match has been applied ; the clouds would probably drift away from the forest and so the rain falling on the crops might be increased.

As Blanford pointed out, the only satisfactory evidence would be that obtained by comparing the rainfall of a district when well supplied with forests with that of the same district when the trees were very few. His application of the principle to the Southern Central Provinces is of sufficient importance to be briefly stated. He gives evidence that in that area prior to 1875, while five-sixths were nominally under forest, so much damage had been done by *dahya* cultivation that by far the greater part of the forests had become devastated. He quotes the introduction of the *Central Provinces Gazetteer* of 1870, where Mr. C. C. Grant says :—

“The tree forests of the Central Provinces have, however, been so much exhausted, mainly owing to the destructive *dahya* system of cultivation practised by the hill tribes, that, except in one or two localities the labours of the Forest Officers will, for many years, be limited to guarding against further damage, and thus allowing the forests to recover themselves by rest. By far the greater part of the uncultivated lands belonging to Government are stony wastes, incapable of producing a strong straight growth of timber.”

Indian Meteorological Memoirs,
Volume III, page 136 ; or Proceedings of the Asiatic Society of Bengal, 1887, Part II, No. 1.

In 1875 the suppression of *dahya* cultivation was taken in hand and with such success that in 1886 Mr. Ribbentrop wrote :—

" My attention was directed, during a recent visit to the Central Provinces to the extensive growth of young forests in areas formerly under *kumri* cultivation. Ten or fifteen years ago, such temporary cultivation was practised throughout the country, and thousands of square miles were thereby laid barren year after year. Since then, this method of cultivation was stopped, and, though a great part of the area affected was subject to annual fires, a more or less dense forest growth has sprung up."

Blanford then compares the rainfall of the area affected by forest preservation with that away from it ; and shows that while the rainfall in the preserved area, averaging about 50", was greater by 6·8" for the period 1876-85 than it had been for the ten years before, the rainfall in the remainder of the Central Provinces had diminished by 2·9". Blanford points out that the area in question, of nearly 50,000 square miles, is large enough to give reliable results, that its history is well-known and considers that the only points on which doubt may be thrown are the reliability of the records and the sufficiency of the periods to yield valid averages. The results of the different stations are so consistent that, I think, the measurements may be trusted, and it would appear that there was an increase of about 9·7" (or 20 per cent.) due to the growth of forest.

Unfortunately, however, it is clear that the periods are too short, and although the rainfall for the southern half of the Central Provinces averaged 48·0" from 1867 to 1875, and 54·6" from 1876 to 1885, the average has only been 50·6" since that time. For the Hyderabad State the averages for the same periods are 26·7", 32·2" and 32·6", showing a similar early improvement of 5·5", which has since been maintained. For the Mysore State the corresponding numbers are 30·2", 33·6" and 35·1"; and for the Madras Presidency 44·4", 46·4", and 46·2". Thus the changes in the southern portion of the Central Provinces extend fully over Hyderabad, and partially into the south of the Peninsula. Let us now see whether the changes in the northern portion of the Central Provinces are shared with Central India East. In the former area the average rainfall from 1867 to 1875 was 51·5"; it fell during the decade 1876 to 1885 to 48·5", and has since risen 46·0"; thus Central India East, with corresponding amounts of 51·1", 43·9" and 45·1", show a much larger fall between the two first periods. Summing up, then it may be said that the changes exhibited by the south and north of the Central Provinces extend in each case over a considerable area to the south and

north respectively, and the difference between them must be due to varying distributions of the strength of the monsoon current, and not to local causes confined to the southern portion of the Central Provinces. Thus, they cannot be regarded as explained by the improvement in forest conditions, although the latter may have played some comparatively unimportant part. Blanford also gives comparisons of rainfalls inside and outside forests and at Ajmer and Dehra Dun ; but as already pointed out, I do not regard such experiments as deciding whether the forest causes an increase of rainfall outside itself.

In the papers submitted by Local Governments the chief arguments on this question appear to be those derived from Baluchistan and the dry area in Burma. In connection with the former it is stated that the forests have diminished materially, but that there has been no appreciable diminution in the rainfall. In the dry zone of Burma my instinct is that the rainfall always has been low, and that the destruction of the forests by human agency has made no perceptible difference to the rainfall, although it has probably led to serious denudation. We know that, for periods comparable with eight or twelve years, the rainfall may be high or low, and I would suggest the possibility that the traces of cultivation of a type requiring more rainfall than there is now may be due to one or more periods of abundant rain. If my impression is correct, the scantiness of the rainfall in the dry zone is almost entirely due to the configuration of the neighbourhood, the valley of the Irrawady there widening out and forming a basin. It is true that the monsoon winds at the ground surface, as recorded by our observatories, run from south to north along the river valleys whose gradients are fairly uniform, and that these winds would scarcely account for the rise in the rainfall of the valley north of Mandalay. But theory and observation in other similar places would indicate strongly that the upper monsoon winds are from the south-west ; the Arakan Yoma would thus cause a diminution of rainfall in the low region sheltered by it to the east, and where the ground rises again to the east of the dry area the rainfall would increase because of the forced ascent against the hills, the air not having lost all its humidity.

On the whole, therefore, I believe that the effect of forests on rainfall is small, and probably does not reach 5 per cent.

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